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# Measurements of electric potential in KFM07A and around drill site 7

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# Measurements of electric potential in KFM07A and around drill site 7

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# Summary


Measurements of electric potential have been carried out in the Forsmark area. The measurements have been done before and after a rearrangement of the electric grounding system at drill site 7. The site has been connected to other drill sites through a non-insulated buried wire, forming a ring-shaped grounding system. Drill site 7 was disconnected from this wire in during the presented measurements, thus forming a local, floating grounding.

Electric potential gradients are suspected to lie behind problems with corrosion of monitoring equipment at drill site 7, and at other drill sites in the area. The use of the HVDC (high voltage direct current) return current electrode at Fågelsundet, north of Forsmark, is known to cause changes in electric potential at Forsmark. The HVDC electrode can be used as both anode or cathode and the change in potential can therefore be either positive or negative. The grounding system of the power plant with its transformers and groundings at the drill sites are suspected to be affected by transferred potentials, i.e. potentials at other groundings that are connected to the same system. The combination of the use of the HVDC electrode and transferred potentials give rise to potential gradients around Forsmark that may be the cause to corrosion problems.

Measurements were made a few times every day at a test station. A reference electrode was placed around 750 m east of the drill site and all measurements were referred to this reference. The potential at the test station could be compared with the electrode current through the HVDC electrode. A linear relation was found between the potential at the control station and the electrode current. However, according to linear regression analysis there is also a DC potential at the control station of around −425 mV at zero electrode current. The cause to this potential is not known, but it is likely that it is not a local anomaly at the test station. This potential makes it difficult to relate other measurements around drill site 7 to the electrode current magnitude, especially during periods with weak HVDC electrode current.

Potential measurements were made along five short surface profiles radially from drill site 7 before and after the change in the grounding system. The same reference electrode was used as for the other measurements. The HVDC electrode current was around −350 A during most of the measurements. The potential increased with 36 to 86 mV for the different measurement stations after the separation of the drill site grounding from the other drill sites. However, there was no trend in the change, i.e. the change was not larger close to the drill site.

The electric potential was measured along KFM07A before and after disconnecting the grounding of drill site 7 from the other drill sites. The same reference electrode was used as for the other measurements. It was not practically possible to know the amount of current through the HVDC electrode at the time of measurements. It turned out that the current was only around −150 A (used as cathode) during the measurements. The potential was unstable in the upper 500 m of the borehole with noisy readings. Measurements were first made before changing the drill site grounding system. The potential in the uppermost 100 m, inside steel casing, was around −230 mV relative the reference electrode. Between 100 and 500 m the potential was around −45 mV with unstable and noisy readings. Below 500 m the potential was around −75 mV with stable readings. The grounding system was then disconnected from the other drill sites, and the measurements were repeated. The results were similar with the only difference in the depth interval 100 to 500 m. The potential in this interval was around −80 mV with the new grounding arrangement. However, the difference relative the first measurements is within measurement uncertainty due to unstable readings. The sharp change in potential at 100 m depth, at the end of the steel casing, thus remained at a similar magnitude, despite the change in the grounding of the drill site.

# Sammanfattning

Mätningar av elektrisk potential har genomförts i Forsmarksområdet. Mätningar har gjorts före och efter en förändring av jordningssystemet för borrplats 7. Borrplatsen har varit hopkopplad med andra borrplatser i ett ringformat jordningssystem via en nedgrävd vajer. Förbindelsen har nu brutits vid borrplats 7, så att denna borrplats nu har en egen jordning som flyter i nivå relativt övriga borrplatser.

Elektriska potentialgradienter misstänks orsaka problem med korrosion på moniteringsutrustning vid borrplats 7, och vid andra borrplatser i området. Användandet av returströmselektroden för HVDC (high voltage direct current) vid Fågelsundet, norr om Forsmark, orsakar elektriska potentialvariationer vid Forsmark. HVDC-elektroden används som både anod och katod och ändringen i potential kan därmed vara antingen positiv eller negativ. Jordningssystemet för kärnkraftverket, dess transformatorer och jordningssystemet för borrplatserna misstänks vara påverkade av överförda potentialer dvs potentialer i andra delar av samma jordningssystem. Kombinationen av användande av HVDC-elektroden och överförda potentialer ger upphov till kraftiga potentialgradienter kring Forsmark som kan ge upphov till problem med korrosion.

Mätningar av elektrisk potential gjordes ett antal gånger varje dag på en testpunkt. En referenselektrod placerades ca 750 m öster om borrplatsen och alla mätningar är relaterade till denna referens. Den uppmätta potentialen på testpunkten kunde jämföras med elektrodströmmen genom HVDC-elektroden. En linjär relation kunde ses mellan potentialen på testpunkten och elektrodströmmen. Enligt linjär regressionsanalys skulle det emellertid finnas en DC potential vid testpunkten på −425 mV vid elektrodström lika men noll. Orsaken till en sådan potential är inte känd, men det är osannolikt att den orsakas av någon lokal anomali vid testpunkten. En sådan potential gör det svårt att relatera andra mätningar till elektrodströmmen, speciellt om denna har varit relativt svag vid mättillfället.

Potentialmätningar gjordes längs fem profiler radiellt ut från borrplats 7, före och efter ändringen i jordningssystemet. Samma referenselektrod användes som för övriga mätningar. Strömmen genom HVDC-elektroden var ca −350 A under de flesta mätningarna. Potentialen ökade med mellan 36 och 86 mV för de olika mätstationerna när borrplatsens jordning hade avskilts från övriga borrplatser. Det gick emellertid inte att se någon trend att ändringen var störst nära borrplatsen.

Den elektriska potentialen mättes upp längs borrhålet KFM07A före och efter att borrplats 7 hade kopplats bort från det gemensamma jordningssystemet för borrplatserna. Det var inte praktiskt möjligt att få information om strömstyrkan genom HVDC-elektroden under mätningen. Det visade sig senare att elektrodströmmen varit ca −150 A (katodström) under borrhålsmätningarna. Potentialen var instabil i de översta 500 m av borrhålet vilket resulterade i brusiga mätdata. Mätningar gjordes först innan ändringen i borrplatsens jordning. Potentialen inuti foderröret, i de översta 100 m av borrhålet var ca −230 mV relativt referenselektroden. Mellan 100 och 500 m var potentialen ca −45 mV med instabila och brusiga avläsningar. Under 500 m var potentialen ca −75 mV med relativt stabil signal. Borrplatsens jordning kopplades sedan bort från övriga borrplatser och mätningen upprepades. Resultaten var likartade med den enda skillnaden att potentialen var ca −80 mV i intervallet 100 till 500 m. Det är dock svårt att säga om skillnaden mot den första mätserien är signifikant på grund av den höga störningsnivån. Den skarpa gradienten vid foderrörets undre kant vid 100 m var alltså ungefär densamma för bägge mätserierna, trots ändringen av borrplatsens jordning.

# Contents

# 1 Introduction

Electric potential gradients are suspected to lie behind problems with corrosion of monitoring equipment at drill site 7, and at other drill sites in the Forsmark area. The use of the HVDC (high voltage direct current) return current electrode at Fågelsundet, north of Forsmark, is known to cause variations in electric potential at Forsmark (Thunehed 2017, 2018). The HVDC electrode can be used as both anode or cathode and the change in potential can therefore be either positive or negative. The grounding system of the power plant at Forsmark with its transformers and groundings at the drill sites are suspected to be affected by transferred potentials, i.e. potentials at other groundings that are connected to the same system, thus setting a grounding point at a different potential compared to the ambient potential. The combination of the use of the HVDC electrode and transferred potentials give rise to potential gradients around Forsmark that may be the cause to corrosion problems (Thunehed 2017).

To reduce the magnitude of potential gradients around drill site 7 it was decided to disconnect it from the ring-shaped grounding that connects several of the drill sites at Forsmark. The idea being that drill site 7 should be less affected by transferred potentials. Measurements of electric potential were carried out in this project along the borehole KFM07A and at the surface around the drill site before and after the connection to the other drill sites was broken. The measurement setup was similar to surveys carried out 2017 (Thunehed 2018).

# 2 Field survey

A field survey was carried out at Forsmark 25 to 27 June 2019 by staff from GeoVista AB. The monitoring equipment had been temporarily removed from KFM07A and the borehole was therefore available for measurements.

Information about the magnitude and polarity of injected current at the Fågelsundet electrode is necessary for the treatment of survey data. That information was made available from Svenska Kraftnät through SKB. It was not possible for the field crew to know the magnitude or the polarity of the HVDC electrode current during measurements and plan the measurements in such a way that all readings were made during similar conditions.

# 3 Electric potential measurements

Earth currents will create an electric potential field. Potential differences can be measured with a high-impedance voltmeter and non-polarizing electrodes.

## 3.1 Equipment

Potential measurements were made with an ABEM Terrameter 4000 instrument. Stelth 1 Ag-AgCl-electrodes from Borin Manufacturing were used for surface measurements, both as reference electrode and for profile measurements. A Stelth 9 Ag-AgCl-electrode was used for borehole measurements. The Stelth electrodes are very stable and the Stelth 9 model is suitable for measurements under high pressure and in high salinity environments, as it is originally developed for deep sea applications.

## 3.2 Survey setup

A reference electrode was placed at Rödgötören, north of Bolundsfjärden (Figure 3-1). All measurements are relative that electrode. Measurements were then carried out along profiles in the investigation area (Figure 3-1). A test station near drill site 7 was measured at least two times per day. Measurements were also carried out in the borehole KFM07A by lowering an electrode down the hole. Cathodic corrosion protection was turned off at drill site 7.

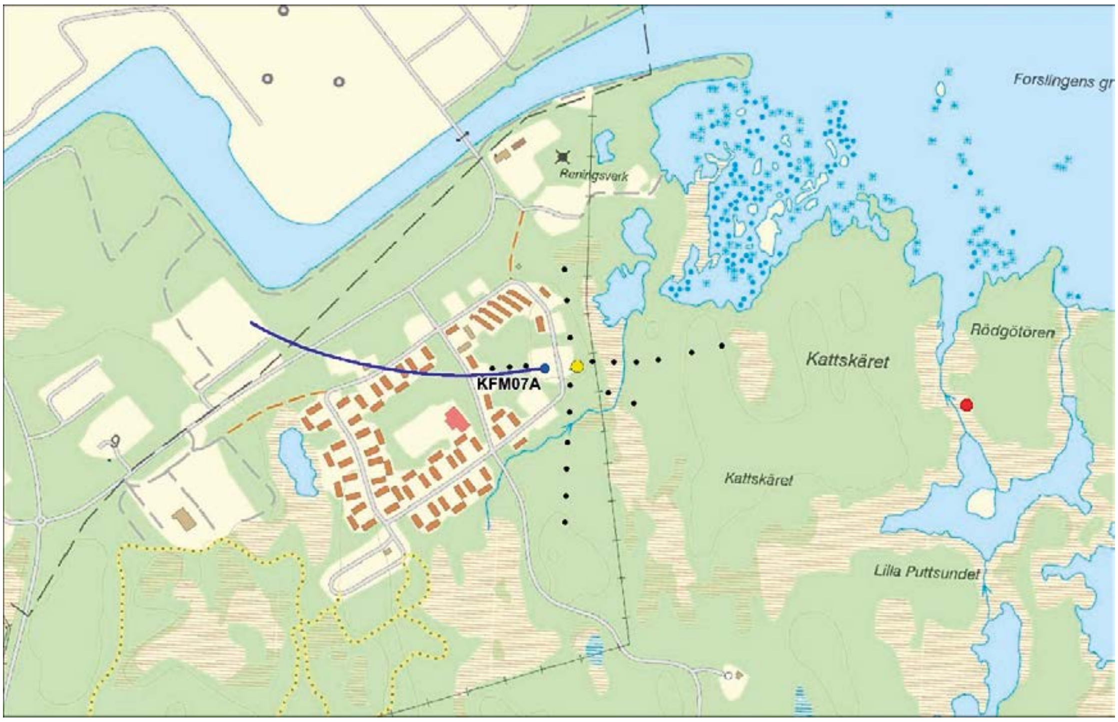


*Figure 3-1.* *Map showing collar and surface projection of KFM07A (blue), reference electrode position (red symbol), test station (yellow symbol) and surface survey stations (black symbols).*

## 3.3 Results

### 3.3.1 Test station

The measurements at the test station are plotted as a function of output current in Figure 3-2. The corresponding data for the 2017 survey are also shown. There is a correlation between the readings and the HVDC electrode current. The solid lines in the graph represents linear regression approximations. According to this, the potential difference varies with −1.51 mV/A between the test station and the reference electrode for the new survey. This result is similar to the value obtained for the 2017 survey (Figure 3-2). The regression lines in Figure 3-2 do not pass through the origin. Instead the intercept is at −435 mV for the new survey and −273 mV for the 2017 survey. The reason for these offsets is not known, neither the reason for the difference between the two surveys, although a gradient originating from drill site 6 is a possible source to the difference. The cathodic corrosion protection system at drill site 6 uses a rather strong current. Obviously, there are sources to DC potentials at Forsmark beside the HVDC electrode.

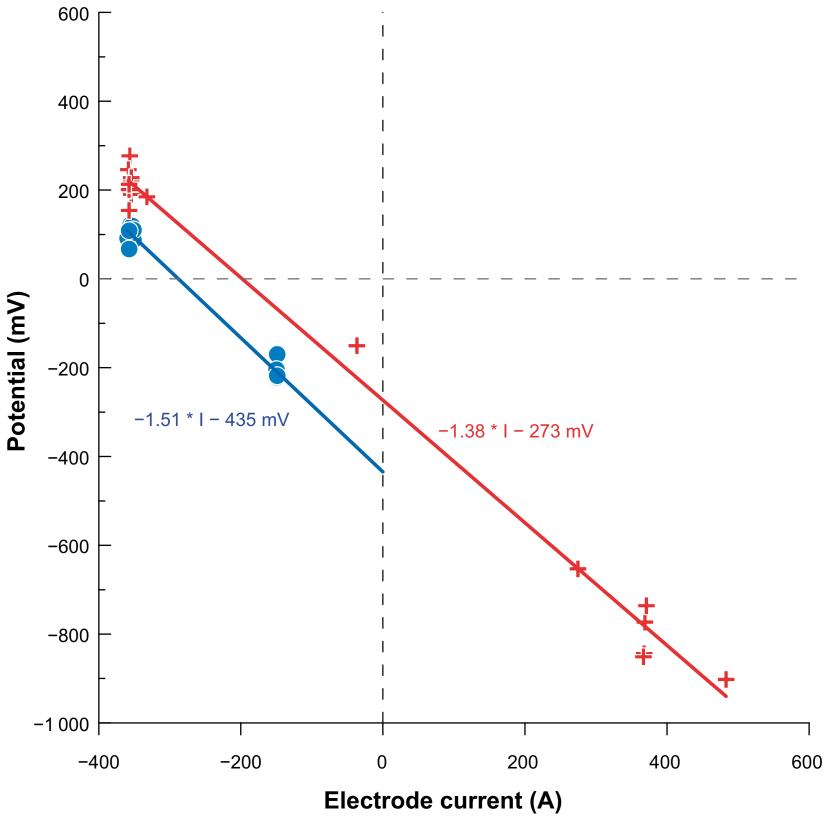


*Figure 3-2. Graph showing the recorded potential difference between the test station and the reference electrode as a function of electrode current at Fågelsundet. Blue symbols: This survey. Red symbols: Thunehed (2017). Solid lines show linear regression solutions for the two data sets. The equations are the regression fit formulas.*

### 3.3.2 Profile measurements

The HVDC electrode was used as cathode during all surface profile measurements, i.e. with negative polarity. The current was around −350 A during all measurements done before the disconnection of the drill site grounding from the other drill sites. The current was also around −350 A during all measurements except five after the change in the grounding system. Those measurements are therefore directly comparable to each other. The HVDC current was around −150 A for the remaining five stations.

The measured electric potential at the surface stations before the change in the drill site grounding can be seen on the map in Figure 3-3. The measurements are done relative the electrode at Rödgötören (Figure 3-1). The stations towards east, closer to the reference, show low potential differences. For the remaining stations there is a tendency for lower values close to the drill site. This might be an indication of influence of transferred potentials, i.e. that the ring grounding systems is at a lower potential compared to the ambient potential at drill site 7.

The measured electric potential at the surface stations after the change in the drill site grounding can be seen on the map in Figure 3-4. Five stations close to the drill site to the west and to the east with negative values were measured when the HVDC electrode current was around −150 A. The remaining stations were measured when the electrode current was around −350 A. The difference due to the change in the grounding system can be seen in Figure 3-5 for those stations where the electrode current was similar for both data sets. There is a general increase in potential after the change. However, this change is not stronger close to the drill site as might be expected. The significant change in potential due to electrode current is most likely an effect of transferred potential from the power plant substation.

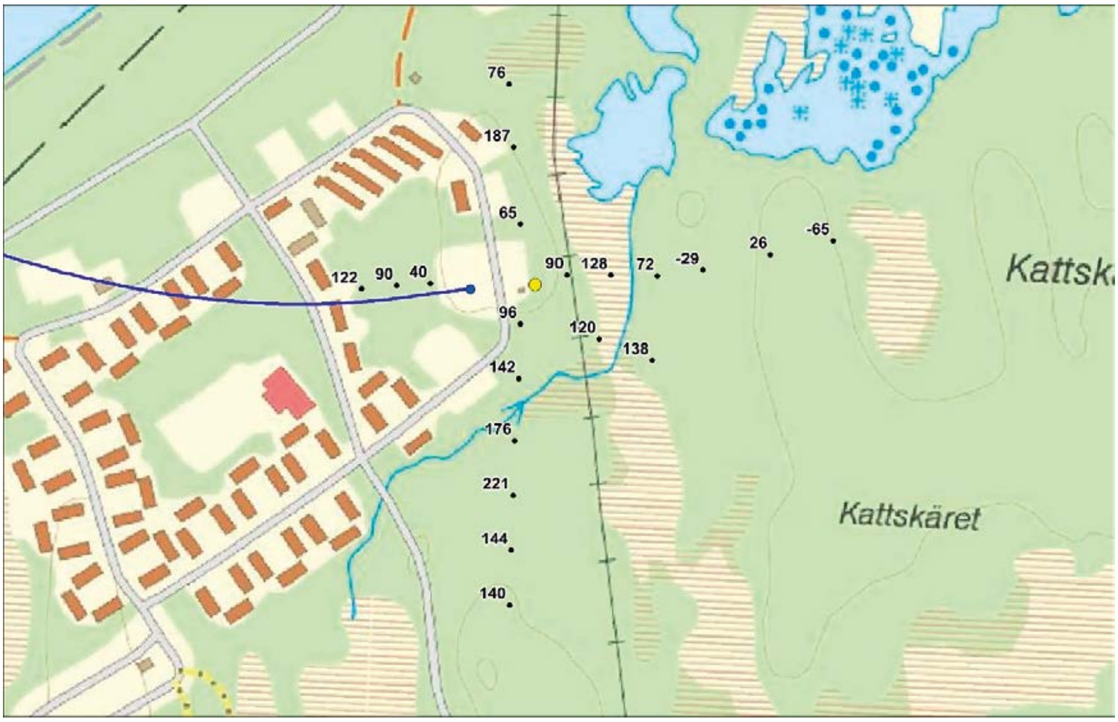


***Figure 3-3.*** *Map showing measured DC electric potential (mV) relative the reference electrode (Figure 3-1) at surface stations, before the disconnection of the grounding of drill site 7 from the other drill sites. The HVDC electrode current was around −350 A during all measurements.*

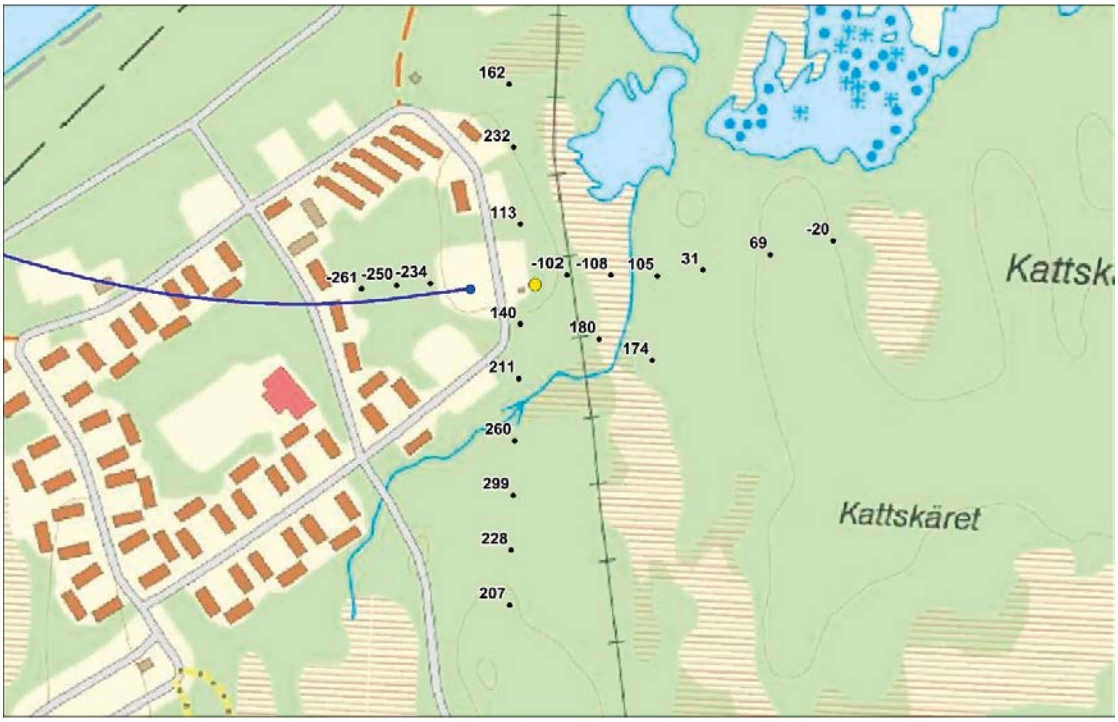


*__Figure 3-4.__ Map showing measured DC electric potential (mV) relative the reference electrode (Figure 3-1) at surface stations, after the disconnection of the grounding of drill site 7 from the other drill sites. The electrode current was around −350 A for all stations except for five station with strongly negative readings close to the drill site towards west and east. The current was −150 A during those measurements.*

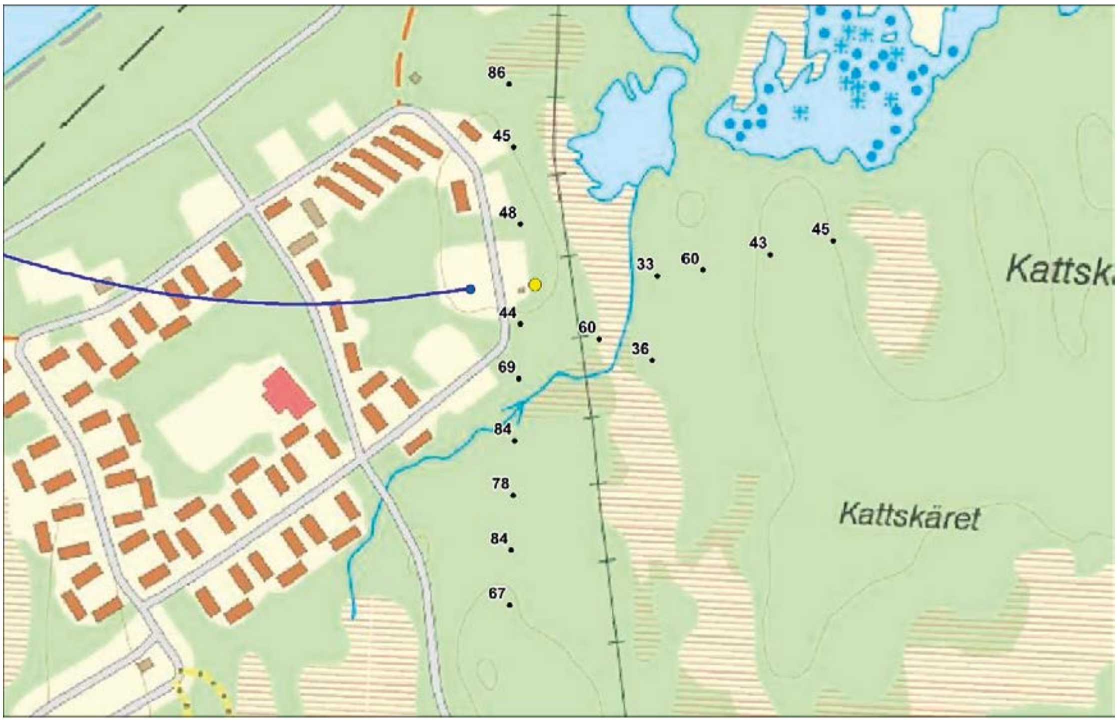


*__Figure 3-5.__ Map showing the difference in measured DC electric potential (mV) after disconnecting drill site 7 from the ring grounding system. Stations that were measured during similar HVDC electrode current are shown.*

### 3.3.3 Borehole measurements

The recorded potential differences along KFM07A are shown in Figure 3-6. All measurements were carried out with a HVDC electrode current of around −150 A. The measurements were noisy and unstable down to around 500 m. The values are around −200 to −300 mV down to 100 m borehole length (which is the lower end of the drillhole casing) for measurements done both before and after the change in the grounding of the drill site. It is not possible to say if there is any significant difference between the two data sets due to the noisy readings. There is a sharp increase in potential below the casing. The increase is possibly slightly larger for the measurements made before the change in the grounding system, but such a difference is not significant in the data due to the high noise level. The values stabilize at around −75 mV below 500 m for both data sets. The noise is weaker at these depths. The potential can be compared with the values for the test electrode on the surface (Figure 3-2) at −150 A electrode current. The potential along the borehole (around −75 mV) is slightly higher compared to the surface test electrode, but still in a similar range.

The new data can be compared with the corresponding measurements made 2017 (Figure 3-6). These measurements were made at HVDC electrode currents of −265 A (< 680 m) and −350 A (> 680 m). The potential level is therefore higher for the 2017 measurements compared to the new data. One thing that can be noted is that the shift in potential at the end of the casing at 100 m depth is larger for the 2017 data. The shift as actually around −1.2 times the HVDC electrode current (in mV/A) for both the 2019 data (before change in drill site grounding) and the 2017 data.

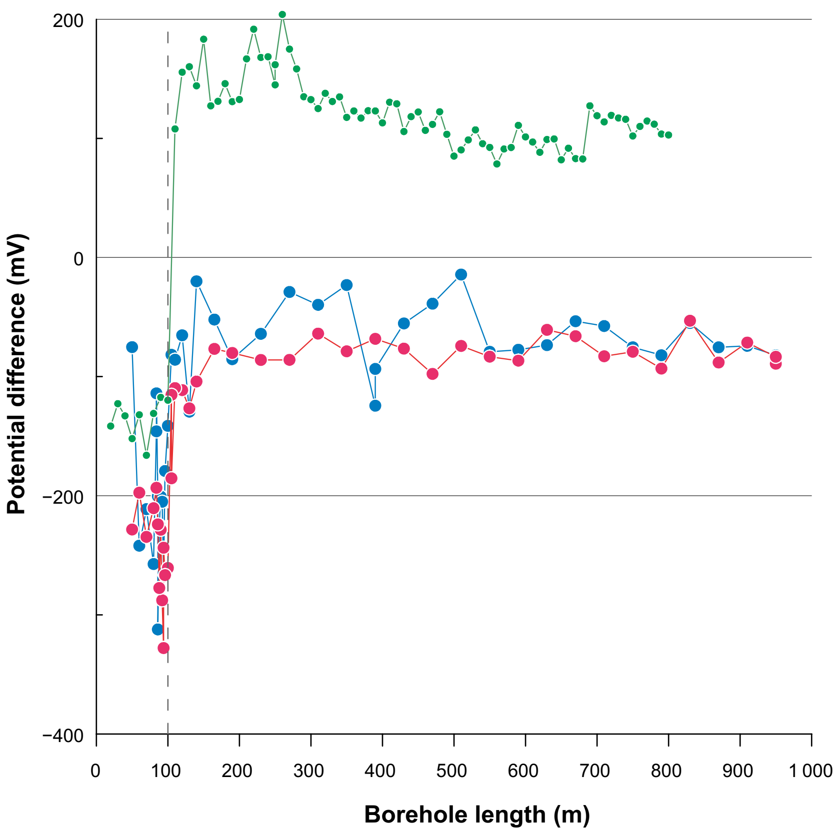


***Figure 3-6.*** *Results from potential measurements in KFM07A. Blue: Measurements made before disconnecting the drill site from ring grounding system. Red: Measurements made after disconnecting the drill site from ring grounding system. Green: Corresponding measurements from 2017. The vertical dashed line marks the lower end of drillhole casing.*

# References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications.

**Thunehed H, 2017.** Compilation and evaluation of earth current measurements in the Forsmark area. SKB R-14-34, Svensk Kärnbränslehantering AB.

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Arkitektkopia AB, Bromma, 2020

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